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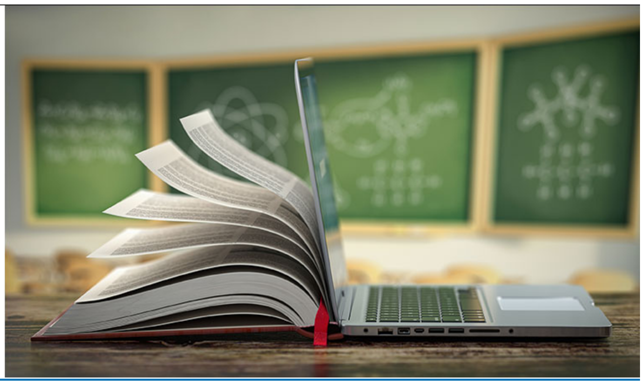

A compact 3-dB coupler with microstrip cells

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Abstract. Research of the design of a coupler with an operating frequency of 1.8 GHz has been conducted. This construction has a small area and can be used in microwave circuits for power division. Suggested construction, taking into consideration the reduced dimensions, has characteristics comparable to the design in the traditional version. Miniaturization of the device was achieved by using synthesized microstrip cells which were installed instead of ordinary sections. The coupler was modeled and fabricated and the measured characteristics are well coincide with the calculations.

1. Introduction
3 dB directional couplers are widely used in various applications of microwave technology, for example, as a part of phase shifters or diagram-forming circuits. The main purpose of such devices is to divide the input power between the outputs in different proportions, the value of which is determined by the wave resistances of the lines. The remaining output of the device will be decoupled due to the mutual destruction of waves, since the condition for summing waves with a phase difference of 180 degrees is met. The main parameters such as the area, bandwidth, and attenuation in the frequency band and phase difference between outputs can be highlighted as most important. With operating frequency decrease, quarter-wave sections lengths will increase which will cause device's area growth. For mobile devices, the area is critical and for this reason it is necessary to apply various design approaches to achieve the miniaturization of the device, not only preservation of characteristics but also the manufacturability. In order to achieve the solution, the approaches described in works [1] – [19] can be used. Directional couplers operating in the decimeter wavelength range (0.3-3 GHz), have the largest area, which is why researches on miniaturization of such devices is mainly conducted in this range. Our work's purpose is to model the design of a compact coupler using microstrip cells which dimensions are significantly smaller compared to devices with conventional transfer lines.

2. The main part
The basic elements of standard couplers are quarter-wave sections. They determine the area of the device on the printed circuits. Depending on the number of connected stubs, the amount of bandwidths will change. The more stubs are connected, the wider the band. However, if the number of loops is more than 5, the wave

resistances of the lines become so large that they are difficult to implement in practice. Before starting the miniaturization procedure of the coupler, the Cadence AWR DE 14 software designs its topology in the traditional version with a central frequency of 2 GHz. FR4 acts as a microwave substrate. TXLine allowed quickly and easily calculate the width and the length of λ/4 sections. The area of the coupler is equal to 100 mm2 (figure 1), and its graph of S-parameters and phase from frequency is shown at figure 2 and figure 3.

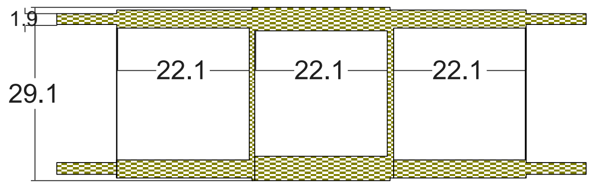

Figure 1. Standard layout of a four-stub coupler obtained in AWR.

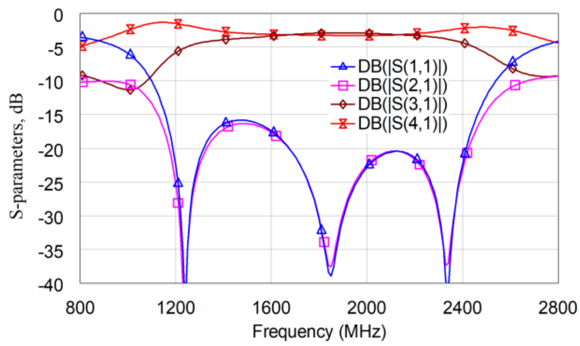

Figure 2. Graph of S-parameters from the frequency of the standard coupler

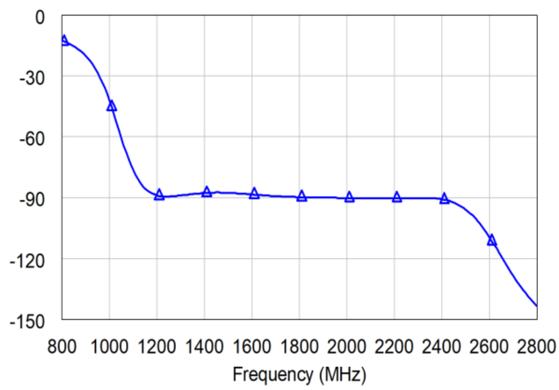

Figure 3. The phase difference between transfer coefficients at the output of the coupler.

The coupler is working at a central frequency of 1.8 GHz on normal sections with a bandwidth of 76%, with an interchange level of -15 dB. The values of the transfer lines coefficients at a central frequency have values of -3.8 dB and the maximum imbalance in the band is 5.5 dB. The phase difference between the outputs is 90 degrees. In the inner space of the coupler enclosed between λ/4 sections there is a large area which is not used in any way. In this regard the elements of the microstrip cells will use this area and thus increase the efficiency of reducing the occupied area of the coupler. Cells consist of inductive and capacitive elements connected in series and thus are low-pass filters. The filter is configured in such way as to get minimum transfer coefficients in the coupler's bandwidth and provide 90-degree phase overrun at the center frequency. The calculated cells were installed instead of λ/4 sections and the resulting layout of the coupler as a result of this replacement is shown in figure 4. Compact coupler's characteristics are shown in figure 5 and figure 6. The area of the compact coupler is 72.8% less and equal to 541 mm^2.

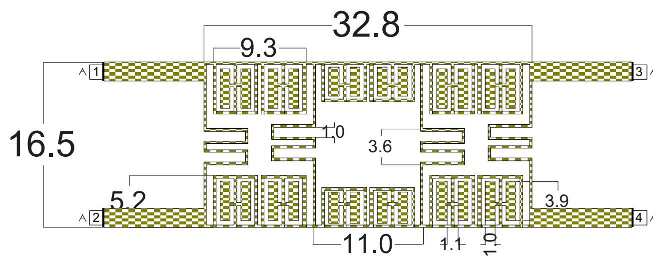

Figure 4. The compact coupler.

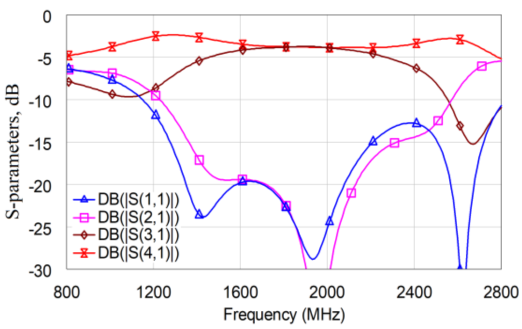

Figure 5. The frequency dependence of S-parameters obtained in AWR for the compact coupler.

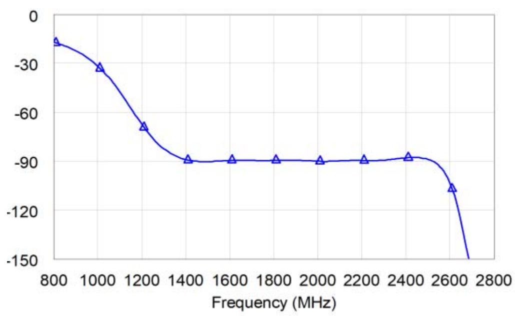

Figure 6. The phase difference between transfer coefficients between the outputs of the coupler.

The cell coupler operates at the central frequency of 1.8 GHz with a bandwidth of 52%, with a decoupling level of -15 dB. The values of the transfer coefficients at the central frequency have values of -3.75 dB and the maximum imbalance in the band is 2.5 dB. At the same time phase difference between the outputs is 90 degrees. It should be noted that as a result of miniaturization there are such negative moments as an increase in attenuation in the frequency band and a reduction in bandwidth. Due to the fact that it is necessary to check theoretical calculations in practice, a model of the coupler in question was made. Its photo is shown in figure 7. The field experiment was performed using the vector chain analyzer Rode&Shwarz ZVA24 (figure 8, 9).

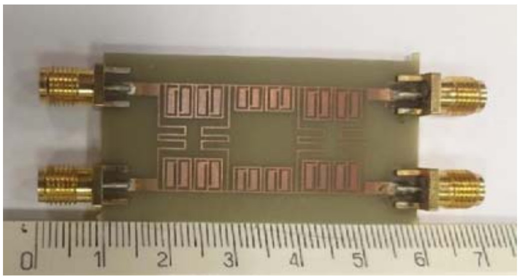

Figure 7. The model of the compact coupler.

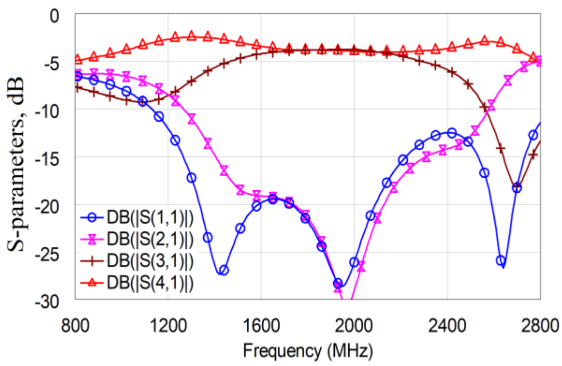

Figure 8. The frequency dependence of S-parameters obtained as a result of a field experiment.

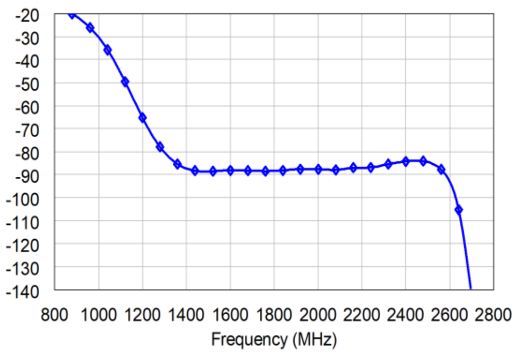

Figure 9. The phase difference between transfer coefficients at the output of the manufactured coupler.

The model is working at the central frequency of 1.9 GHz with the bandwidth of 57.4%, with a decoupling level of -15 dB. Values of the transfer coefficients at the central frequency have values of -3.85 dB and the maximum imbalance in the band is 3.5 dB. At the same time phase difference between the outputs is 90 degrees. Experimental and theoretical characteristics have minor differences which may be related to the manufacturing inaccuracies, differences in the permittivity of the material in practice and in the AWR. Comparison of the miniaturization results can be found in Table 1.

Table 1. Comparison of the numerical and measured results

Parameters	**Standard**	**Compact**
Bandwidth, MHz	1370	1100
Area, mm^2	1993	541
Relative Area, %	100	27.2
Central Frequency, MHz	1800	1900
The Phase Outputs	90	89

3. Conclusion

In this work model of the compact coupler was suggested. It has dimensions three times smaller than the coupler's on conventional transfer lines with the same operating frequency and substrate parameters. The results of mathematical simulating in the AWR software and field experiment showed a good match of device characteristics. The disadvantages of miniaturization can be considered a reduction of the frequency band, an increase of the attenuation in the band and the complexity of the design. These facts are leading to difficulties in manufacturing of the device. The compact coupler can be used in the construction of power supply circuits for antenna arrays and compact phase shifters.

ACKNOWLEDGMENTS

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